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VI ALL - UNION MEETING ON LOW TEMPERATURE PHYSICS

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(Following is the translation of an article by R. Chentsov entitled "VI Vsesoyuznoe Soveshchanie po Fizike Nizkikh Temperatur" (English version above) in Uspekhi Fizicheskikh Nauk (Progress in the Physical Sciences) in the section entitled Soveshchaniya i Konferentsii (Meetings and Conferences), Vol. LXXI (71), No. 2, June 1960, Moscow, pp. 339-347.)

The VI All - Union meeting on low temperature Physics took place in Sverdlovsk from 27 June - 2 July 1959.

About 5o papers were discussed during the conference. Besides the general sessions, there were also seminars for discussions of topics, only of interest to smaller groups. During these seminars about 2o reports were presented. The chairmen of the different seminars gave the contents of these reports during the course of the general sessions. About 3oo people participated in the work of this meeting. Among them were about 2oo foreign participants - also physicists from Moscow, Leningrad, Kharkov, Kiev, Tiblisi, Sukhuma, Krasnoyarsk, Dubna and other cities, including scientists from the Chinese People's Republic, Poland and Hungary. The general sessions were dedicated to magnetic phenomena at low temperatures, superconductivity, electron characteristics of metals, polymorphism, supersonics, semi-conductors. The seminar discussions embraced: papers on studies of liquid helium; methods of producing low temperatures, and techniques of physical experiments at low temperatures; mechanical characteristics of metals, ferromagnetic resonance; low temperature characteristics of semi-conductors. Two big seminars were conducted by theoreticians.

The opening of the conference, an audience of 9oo people was in attendance, heard the chairman on problems of low temperature and solid state Physics, the academician P.L. Kapitsa. He discussed the general state of the art of low temperature Physics, and analyzed the history of the development of Physics is Sverdlovsk. P.L. Kapitsa emphasized particularly the important position extremely pure substance hold in the work of low temperature Physics. It is well known that a temperature decrease leads to a reduction in the distortion, caused by the thermal motion of the atoms, of the crystal lattice. Obviously

it would be useless to cool down a sample, we intend to investigate, to temperatures, at which the distortion of the lattice due to thermal motion, becomes many times smaller than the "static distortion" of the lattice due to impurities, dislocations, and similar defects of the crystal. P.L. Kapitsa noted that at the present time it becomes possible to grow some crystals with such a degree of chemical and physical purification that the distortion of their lattices corresponds to the thermal oscillations of atoms at temperatures much lower than $1^{\circ}K$. Work on the techniques of producing extremely pure substances, and the development of super-sensitive analytical methods (particularly the activation analysis), belong to today's most acute problems.

A. FERROMAGNETIC AND ANTI-FERROMAGNETIC CHARACTERISTICS OF SUBSTANCES AT LOW TEMPERATURES

That ferromagnetism was included in the program of this meeting is due to the fact that studies conducted at the Sverdlovsk Institute of Physics of Metals belong to the leading scientific investigations in this field. The scientists of this institute have contributed not only some of the most important papers on the theory of ferromagnetic metals and alloys, but also have made progress in their experimental investigations, and have developed many important technical applications. In recent times research was done at the institute on low temperature magnetism.

The report by S.V. Vonsovskii, Yu. P. Irkin and V.G. Shavrov (Institute of Physics of Metals, Academie of Sciences, USSR) discussed the Hall-effect in ferromagnetic matter. Hall's electro-motive force (e.d.s. - elektrodvizhushchaya sila ?) in non - ferromagnetic matter is determined by the external field: $E_H \sim R\,H$. From experiments we know that in ferromagnetic matter $E_H \sim (R_o\,H + R_S\,M)$.

with M - the magnetization,

while at high temperatures the "spontaneous" Hall constant R_S exceeds the normal Hall constant R_o by a factor of ten, and is, in addition, characterized by a sharp temperature dependence. The paper makes an attempt to explain some of the abnormalities of the Hall - effect in ferromagnetic matter. They base their explanation on the (s - d)-exchange of the model, taking the spin-orbital interaction into account. They show that the change of R_S with temperature can be connected directly to the temperature dependence of the square of the electrical resistance. Thus they obtained an equation for the temperature dependence of R_o of ferromagnetic matter. Its electrical resistance is determined by the collision of electrons with phonons and ferromagnons.

N.V. Vol'kenshtein and G.V. Fedorov (Institute of Physics of Metals) investigated experimentally the temperature dependence of the Hall-effect in pure ferromagnetic nickel, iron, and cobalt. The measurements were done between 300 and 4.2°K. They found that even the common Hall constant R_o of ferromagnetic metals has an abnormal temperature dependence, which is different from the temperature dependence R_o of non-ferromagnetic matter. Their results lead them to the conclusion that the Hall-effect in ferromagnets depends not only on the magnitization but also on the crystallographic structure.

The report by E.A. Turov and A.I. Mitsek (Institute of Physics of Metals) dealt with a theoretical investigation of the temperature dependence of constant anisotropy of ferromagnetic substances, whose crystals have different symmetries. They applied the phenomenological theory of spin waves, and succeeded in connecting the temperature dependence of constant anisotropy to the temperature change of spontaneous magnetization. The authors noted that precision measurements of constant magnetic

anisotropy at low temperatures acquire great importance as far as checking the fundamental principles of the theory of ferro-magnetism is concerned.

A.S. Borovik - Romanov and I.E. Dzyaloshinskii (Institute for Problems in Physics, Academy of Sciences, USSR) studied experimentally and theoretically piezomagnetism in anti-ferromagnetic fluorides of cobalt and manganese. Anti-ferromagnetic materials may have a piezomagnetic effect, provided they are of a particular structure. This effect can be considered as the emergence of weak ferromagnetism in anti-ferromagnetic matter, due to a specified deformation of the magnetic symmetry. Piezomagnetism can, in the above materials, only appear as the result of shear stresses. The research was conducted on mono-crystals. They used very sensitive scales, which would measure forces of 10^{-7} g, to measure the magnetic moments as a function of the field. Piezomagnetic effects were discovered in both samples. They emerged in the deformed samples at spontaneous magnitization. The magnitude of the spontaneous piezomagnetic moment constituted several CGSM units per 1 mol (about 0.01% of the nominal moment of ferromagnetic materials). P.L. Kapitsa noted how closely in this study theory and experiment agreed. The success of the research depended to the greatest extent on the procurement of mono-crystal samples of these hard to "grow" crystals (N.N. Mikhailov of the Institute for Problems in Physics supplied the samples).

E.A. Turov and V.E. Vzdornov (Institute of Physics of Metals) developed a theory of weak ferromagnetism in ortho-ferrites of the rare earth class - compound, with rhombic lattices, of the type $MeFeO_3$ (where Me - a rare earth element between samarium and lutecium). They showed the possible directions of spontaneous, weakly ferromagnetic, moments as a function of the magnetic structure. Also investigated was the magnetization

change in the magnetic field. Weakly ferromagnetic materials of the above type possess a number of particular characteristics, distinguishing them from mono-axial weakly ferromagnetic materials, which were studies by Dzyaloshinskii.

A.S. Borovik - Romanov reported during the discussion on research conducted by N.M. Kreines at the Institute for Problems in Physics in the field of magnetic characteristics of cobalt-sulfate. Without a field this substance (isomorphic with respect to ortho-ferrites) does not possess weak ferromagnetism, however in a magnetic field it changes over to a weakly ferromagnetic state.

E.A. Turov and N.G. Guseinov (Institute of Physics of Metals) found the magnetic resonance frequency of a rhombohedral, weakly ferromagnetic , anisotropic crystal (either of the hematite or the manganese-carbon type). The corresponding wave lengths lie in the millimeter and centimeter ranges. They found the resonance frequnecy as a function of the magnitude and direction of the magnetic field. The results tally with the measurements made by Japanese authors. The magnitude of "Dzyaloshinskii's field", determined from the date of the resonance measurements, agrees with the values obtained through magnetic measurements to within a few per cent. P.L. Kapitsa emphasized the great importance of experimental research in the resonance field for the study of this and many other phenomena of low temperature Physics.

V.V. Tolmachev (Mathematical Institute, Academy of Sciences, USSR) reported on a mathematical theory of ferromagnetism. He showed that Heisenberg's model of a ferromagnetic material is mathematically equivalent to the problem of the quadruple (on the) Fermi-operator of the Hamiltonian, which was formed earlier in the theory of superconductivity. The speaker referred to a number of advantages of the suggested method.

M.O. Kostryukova (Moscow University) measured the heat capacity of nickel-, zinc-, and nickel-zinc ferrites (20% Ni). The measurements were made between the liquid hydrogen temperature and 2° K. At 10° K a certain deviation in the heat capacity of the combined ferrite was noted. The heat capacity is, in this case, in the vicinity of the helium temperature, about 170 times higher than the heat capacity of the pure nickel ferrite. The temperature dependence of the heat capacity of the mixed ferrite at helium temperatures is expressed by the equation $AT^3 + BT^{3/2}$, furthermore, the cubic term is about 30 times larger than the heat capacity of the lattice.

P.A. Alikhanov (Institute for Problems in Physics) held a very interesting lecture. He studied neutronographically the anti-ferromagnetic fluoride of nickel over a wide temperature range. His neutronograph technique was significantly improved, compared to the methods of other authors. N.N. Mikhailov, of the same institute, prepared the anhydrous NiF_2 compound. Alikhanov studied also the temperature dependence of the magnetic reflection intensity; he found it to be approximately a T^2-function. He came to the conclusion, through his study of the reflection intensity ratio (100) and (001) (the latter is well resolved due to the increase in resolving power) that the magnetic moments of Ni^{++}-ions are located in the plane (001). He also showed that NiF_2 possesses weak ferromagnetism. The spontaneous magnetization vectors of the sub-lattice form an angle of 13° with the [100] direction.

N.V. Vol'kenshtein and M.I. Turchinskaya (Institute of Physics of Metals) did experimental research on the magnetization anisotropy of the "disordered" Ni_3Mn alloy, at helium temperatures. These studies were conducted on mono-crystal samples, cut - out along directions [111], [110], and [100].

The magnetization curves of these samples were plotted for room-, nitrogen-, hydrogen-, and helium temperatures. Direction [111] remains at all temperatures the direction of weak magnetization. The magnitude of the moment in a field of about 100 oersted, with rapid cooling to 77° K, grows sharply, while with a further temperature drop it starts to decrease. The growth of the magnetic anisotropy cannot explain the increase of the saturation field due to the temperature drop from nitrogen to helium, even for the direction of the weakest magnetization. E.A. Turov suggested that this discontinuity could be explained as a result of the matter, in the magnetic field, changing from the antiferromagnetic to the ferromagnetic state.

O.S. Galkina and L.A. Chernikova (Moscow University) measured the electric resistance of ferromagnetic copper-nickel alloys at 8° - 30° K, as a function of the temperature. They also measured the resistance change in a magnetic field at 20°K. They found a correlation between both effects. The results are considered to be a confirmation of the fact that electron scatter influences ferromagnetic materials.

E.I. Kondorskii, O.S. Galkina and L.A. Chernikova (Moscow University) discovered that the electric resistance of copper-nickel alloys near the Curie point showed some abnormal behavior. For example, the resistance of a 59% nickel - 41% copper alloy has a low maximum (about one half of one per cent), which lies several tens of degrees above the Curie point. This effect decreases in presence of a magnetic field. They suggested an explanation of these phenomena by introducing the idea of magnetic fluctuations near the point of ferromagnetic transition.

E.I. Kondorskii and V.L. Sedov (Moscow University) studied the influence of compression, acting in all directions, on magnetic saturation and electric resistance. This research was conducted on iron, nickel and some other ferromagnetic alloys at

low temperature.

V.E. Rode (Moscow University) measured the susceptibility of nickel alloys - copper and nickel - aluminum in fields of up to 7000 oersted (in the paraprocess domain). The susceptibility of the paraprocess is, over a wide range of temperatures and concentrations, proportional to $TH^{-1/2}$. M.I. Kaganov noted that the susceptibility values found, were of the same order of magnitude as the values considered necessary for a field to bring about a change-over of the internal wave functions ($\sim 10^8$ oersted).

B. SUPERCONDUCTIVITY

At the present time the most important remaining problem in superconductivity is, after the work of Bardin, Cooper (Kuper) Shepherd (Shefferd), and N.N. Bogolyubov, who formed the basic principles of the microscopic superconductivity theory, to find out whether it is possible to predict from theory new superconductors with higher critical temperatures. The question of a criterion for superconductivity started a lively discussion during the meeting. This question was raised mainly through a lecture by S.V. Vonsovskii and M.S. Svirskov (Institute of Physics of Metals). They showed (starting with a study of models of metals in the spirit of the microscopic theory) that there exists a definite correlation between the characteristics of superconductivity and the magnitude of the effective charge of the metal ions. A calculation of the effective charge of ions (using Slater's (Sleiter) method) showed that the effective charge of a superconductor was, with one exception, more than three. However, even this criterion (like others, e.g. Mathias' (Mattias') criterion) is not complete. This becomes, for example, apparent in the fact that one and the same metal, but with different crystallographic modifications, will or will

not act as a superconductor.

I.B. Borovskii (Metallurgical Institute) made an analysis of the fine structures of X-ray spectra (emission and absorption) of a series of superconductive compounds, and also tried to compare the peculiarities of these spectra with the phenomenon of superconductivity.

N.E. Alekseevskii noted during the discussion that empirically we observe a correlation between the critical temperature of bismuth alloys and the atomic radius of the second metal. If we want to talk about more fundamental criteria, then, for example, the important factor could be the number of "conducting" electrons per unit volume. However, up to now the question of a superconductivity criterion remains open.

V.L. Ginzburg (Physical Institute, Academy of Science, USSR) compared experimental data with the Ginzburg - Landau macroscopic theory of superconductivity. The equations of this theory were modified in such a manner (demonstrated by L.P. Gor'kov, see later on down), as to account for the fact that the universal charge, appearing in this theory, is equal to twice the charge of an electron (the total charge of a Cooper (Kuper) pair). He found the values of the parameters, used in this theory, for tin and (less reliable) for aluminum; the value $\varkappa$ for tin is about o.15; for aluminum this value is about an order of magnitude smaller. V.L. Ginzburg mentioned also his ideas concerning the comparison between the macroscopic theory and the results for thin films (which has been done before frequently). The significant influence of the free path of the electrons on the characteristics of superconductors (mainly on the penetration depth of the magnetic field) was found only recently. Probably we may say without doubt that we cannot deduce directly from the characteristics of the films the pene-

tration depth, which characterizes solid metals. From the point of view of the contemporary theory it is rather advisable to study thin films as if they were alloys, where the penetration depth and other characteristics have a completely different significance. From this point of view the experimental results of N.V. Zavaritskov's analysis of thin films appear incomprehensible. However, N.E. Alekseevskii showed during the discussion that the data on the critical fields of films, which B.K. Sevast'yanov (Crystallographic Institute, Academy of Sciences, USSR) found recently, tally well with Zavaritskov's data for fims and his data for solid metals.

L.P. Gor'kov (Institute for Problems in Physics) reported interesting news. In his first paper he deduced from the microscopic theory the equations of Ginzburg and Landau's macroscopic theory. He showed that Ginzburg-Landau's equations are consequences of the microtheory, where the ψ - function assumes the meaning of the wave function of a Cooper (Kuper) pair. He also found the meaning of the $\varkappa$ parameter: its magnitude indicates whether or not a certain metal belongs to the London (Londonovskii tip) or to the Pippard (Pippardovskii tip) type of superconductor; he found an expression for this parameter in terms of the microtheory. Corresponding studies were done also for alloys which are different, mainly in their large $\varkappa$ - value (larger than $(2)^{-1/2}$). He showed that if for pure metals the validity region of the macroscopic theory is limited to the immediate vicinity of T_K (10^{-3} - 10^{-4} degrees for a Pippard-type metal), then for an alloyed metal this region is significantly widened. L.P. Gor'kov gives in his second paper a microscopic theory on the effect of magnetic super-cooling, along with an expression for the critical field of super-cooling. He shows that in strong fields superconductors of the London-type have to have, with respect to super-cooling effects, characteristics of super-con-

ductive alloys.

S.V. Vonsovskii and M.S. Svirskii (Institute of Physics of Metals) studied theoretically the problem of superconductivity of ferromagnetic metals. They found that the (s-d)-exchange of interaction has to show some influence on the critical temperature of superconductors, and also on the characteristics of the superconductive phases. In particular, the interaction between electrons and ferromagnons has to reduce the electron - phonon attraction interaction and thus oppose superconductivity. The authors presented an interesting hypothesis on the, in principle possible, appearance of low temperature phonon ferromagnetism as a result of strong electron-phonon interaction of internal electrons (analogous to the appearance of superconductivity as a result of electron-phonon interaction of "conducting" electrons).

G.F. Zharkov (Physical Institute, Academy of Sciences, USSR) investigated the problem of the pure and the intermediate superconductive states, which is encountered in ferromagnetic superconductors. These states are possible under certain conditions in some intervals of the magnetic fields. He calculated the structure of the intermediate state of a slab in a normal field (in the spirit of Landau's study).

A.I. Shal'nikov and M.I. Ginzburg (Moscow University) dealt in their report with the characteristics of thin films. The films, with a thickness between o.l micron and several microns, were of tubular shape, and were applied on a glass backing at room temperature by simultaneous evaporation inside a high vacuum. They investigated the critical magnetic fields and the critical currents in the vicinity of the critical temperature. The results were evaluated on the basis of the Ginzburg - Landau Theory. The influence of temperature and thickness, which can be predicted from this theory, was proven qualitative-

ly; however, the critical currents appear to be unusually low (because of structural defects). The penetration depth was measured to be about o.2 μ - about 3 times more than Zavaritskov's data indicated. M.M. Mikheeva (Institute for Problems in Physics) disclosed during the discussion that she together with N.E. Alekseevskii had also studied the critical currents of a tin film, however, they used a different configuration (circular discs with radial current flow). These films were analyzed with the impulse-method. The films were evaporated on glass backings at room as well as lower temperatures. The $\Delta T = T_K - T$ dependence of the critical current, according to the theoretical $(\Delta T)^{3/2}$ law, can with films, obtained by the first method, be observed only at $\Delta T \leqslant 0.05^{\circ}$; at larger ΔT (but with films and evaporations at liquid nitrogen temperatures already beginning with the smallest ΔT) a linear relation takes over. The absolute value of the critical currents were, however, close to the predictions of the theory. Many participants of the discussion emphasized the most important role of the structures of the films, which actually may be far from the ideal structures, assumed by the theory. It was also recommended to study the films through an electron-microscope. Furthermore, it was noted that it would be desirable to conduct, parallel with the measurements of the critical currents and fields, an investigation of the free paths of the electrons in the films.

Yu.V. Sharvin's and V.F. Gentmakher's (Institute for Problems in Physics) report caused great interest. They studied the penetration depth of the magnetic field in superconductors as a function of the magnitude of the field. This dependence is very interesting from the point of view of specifying more accurately the parameters in the modern version of the Ginzburg - Landau theory. The authors developed an intricate technique for measuring small changes of the penetration depth. The measurements

were made by comparing the frequencies of two oscillators, completely submerged in liquid helium. Inside the self-induction coil, forming the circuit of one of the oscillators, was located a sample, upon which a parallel magnetic field was applied; the frequency of the second oscillator remained fixed. The frequency difference was determined through a pulse method. This apparatus was so sensitive that it was possible to measure changes in penetration depth of o.2 Å. The authors obtained preliminary results for tin. The penetration depth, for weak fields (as was to be expected), grows proportional to H^2; with stronger fields they observed a deviation from this expression. N.E. Alekseevskii mentioned that such a technique, developed by Shalov in the USA, can also be utilized for different measurements of small changes in length (for example, to determine volume changes during the break-down of superconductivity).

N.V. Zavaritskii (Institute for Problems in Physics) reported on this measurements of the thermal conductivity of gallium at temperatures ranging from o.1° to 4.2° K. He investigated samples with different degrees of purity (the resistance ratio at helium and room temperature was between o.oo5% and 1.5%) and with different crystallographic orientations. He measured the thermal conductivity of the superconductive, the normal, and the intermediate states. He observed an anisotropy of the thermal conductivity in the superconductive state, which apparently is the reflection of the anisotropy of the energy-slit width of the gallium spectrum. The thermal resistance, in the intermediate state, increased significantly. This is true not only for the thermal conductivity of the lattice but also for the thermal conductivity of the electrons. The latter effect is apparently connected with the scattering of normal electrons on the boundaries of superconductive and of normal regions.

P.A. Bezugli', A.A. Galkin, and A.P. Korolyuk (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) investigated the absorption of supersonic frequencies of 70 Megacycles (the wave length is of order 0.1 mm) in superconductive tin as a function of crystallographic orientation. The absorption coefficient is strongly dependent on the crystallographic orientation, and is, therefore, in the opinion of the authors, an indication of the anisotropy of the energy slit. The authors obtained results, which, they think, give reason to believe that the critical temperature is a weak function of the crystallographic orientation.

N.N. Zhuravlev, G.S. Zhdanov, and N.E. Alekseevski (Moscow University) presented a paper on the superconductivity of bismuth compounds. The great number of bismuth alloys, which were investigated by the authors, and many of which were superconductive, allowed to establish two groups of isomorphic superconductive compounds of bismuth; one with alkali-metals and the other with metals of the 8^{th} periodic group: Type ABi_2 (A = K, Rb, Cs) and type BBi (B = Ni, Rh, Pt). They found a number of correlations between the critical temperature and the structural characteristics of the alloys (atomic radii of the components, Bi - Bi distance). They also expressed some ideas about the probable structure of superconductive modifications of pure bismuth.

C. ELECTRON CHARACTERISTICS OF METALS AT LOW TEMPERATURES

The report by N.E. Alekseevskii and Yu. P. Gaidukov (Institute for Problems in Physics) "Investigations of Magnetoresistive Characteristics as a Method of Studying the Surfaces of Fermi - Metals" and the paper by I.M. Lifshits and V.G.

Peschanskov (Physical-Technical Institute, Academy of Sciences, Ukranian SSR, Kharkov University) "On the Theory of Magnetoresistive Phenomena" (the lecture was given by N.E. Alekseevskii) were rather detailed and interesting. The further development of the results, which were presented at the last meeting in Tiblisi, lead to a study of the resistance of mono-crystals of gold, silver, copper, tin, mercury, thallium, and gallium in a magnetic field. The results of this study allow us to come to the firm conclusion that all these metals have open Fermi-surfaces. For copper and silver, similarly as for gold, an averaging over the angles leads to a linear law of resistance change of poly-crystals in magnetic fields. This relation has been discovered by P.L. Kaptsa. This law can be considered as a criterion for the existance of open Fermi-surfaces on single valence metals. Based on stereographic projections of particular directions of the magnetic field is the conclusion that for gold, silver, and copper the Fermi-surfaces represent space lattices, formed by corrugated cylinders with their axes along [111] and [110] (gold, silver) [111], [110], [001] (copper). The Fermi-surface is apparently, in the case of thallium and gallium (less symmetric structures), a corrugated plane. Lead and possibly tin have Fermi-surfaces of the first kind, with the cylinder axes along [111] (lead), [010] and [111] (tin). A comparison of the data with the computed results of some actual Fermi-surface types, done by I.M. Lifshits and V.G. Peschanskii, made it possible to find the values for parameters of the Fermi-surface of gold. A value of almost exactly 1 electron per atom was obtained as the electron concentration. The measurement of Hall's constant for silver, performed for two direction of the magnetic field (minimum and maximum of the polar diagram) resulted in finding the radius of the Fermi-sphere; it is equal to 6.1 eV. Also estimated was the diameter of the tubes, which

form the space lattice. N.E. Alekseevskii reported also on attempts to influence Fermi-surfaces through pressure (for tin: 4oo atms of pressure did not yield any results) and alloying (solid solutions of lead - sodium do apparently show the possibility of such effects). In summary, it is possible to point out that silver, gold, copper, lead, tin, thallium, gallium, zinc, cadmium, lithium can be counted (with a greater or lesser degree of certainty) among metals with open Fermi-surfaces, bismuth, antimony, indium, sodium, beryllium, tungsten, aluminum, and mercury belong to those with closed Fermi-surfaces.

E.S. Borovik and V.G. Volotskaya (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) investigated magnetoresistive phenomena of indium and aluminum in strong effective fields, which they could get only because of the high purity of the metals (resistance ratios at 4.2° K and $29o^\circ$ K were o.oo8% and o.o4%, respectively). The ratio of the free path to the radius of the Larmor orbit was several tens. They measured also the Hall effect and the resistance, as a function of the magnetic field. With aluminum they observed a saturation of the resistance in the magnetic field function, which refuted Leute and Olson's (Lyuta, Olsen) results, which they obtained in pulse type fields. The Hall field in strong magnetic fields exceeds by several times the electric field along the current. The results for indium are witnesses in favor of its Fermi-surface being closed.

I.N. Lifshits (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) reported interesting theoretical findings. He studied possible abnormalities of the magnetoresistive effects in regions of great pressures. These deviations are the result of a change in the topology of the Fermi-surfaces because of the high pressure, which must naturally lead to a sharp change in the characteristics of the metal - to a phase

transition. The peculiar electron density, observed during transition, must lead to a change in thermodynamic characteristics (thermal conductivity, magnetic susceptibility, compressibility), while the change in dynamic characteristics must naturally result in a change in the kinetic coefficients (for example, change in resistance). It is curious to note that the peculiarities in the first and second group of characteristics appear along different directions from the transition point. The thermodynamic potential, as a function of the pressure, at $p > p_K$ (where p_K - pressure of transition) contains the term $(p - p_K)^{2½}$, i.e. the transition can be called, using Ehrenfest's (Erenfest) terminology, "transition of the 2½-th - kind". Estimating p_K will yield values in the tens of thousands of atmospheres. High pressures are, to a certain degree, equivalent to alloying (alloying of the order of tenths of one per cent are required), however, alloying smears out the transition.

L.S. Kan and B.G. Lazarev (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) reported preliminary results of experimental investigations of the influence high pressures (say up to 17oo atms), combined with low temperatures, have on the resistance of mono-crystals of zinc and tin. They observed an increase in resistance of 2o - 3o% due to the application of pressure. The zinc sample, having its axis oriented closely along the direction of the hexagon axis of the crystal, exhibited a particularly large value of the effect, and also a complicated non-monotone dependence of the resistance upon the pressure.

G.E. Zil'berman and I.O. Kulik (Kharkov) conducted a theoretical study of the problem of quantum oscillations of the electron yield, caused by the photoeffect, as a function of the magnetic field. A study of these oscillations, in contrast to

other methods of investigating the electron structure, will apparently yield information not only on the uppermost Fermi-surface, but also on deeper situated layers.

A.A. Galkin and A.P. Korolyuk (Physical-Technical Institute, Academy of Sciences, Ukranian SSR, Radiotechnical and Electronic Institute, Academy of Sciences, USSR) studied the oscillations of the absorption coefficient of supersonic frequencies between 17 and 2oo Megacycles of mono-crystals of zinc, tin, and bismuth in a low temperature field. This technique furnishes the chance to investigate the structure of the Fermi-surfaces of metals. The period of the oscillation (as function of H^{-1}) is constant, but depends on the frequency. They found this phenomenon to be strongly anisotropic.

N.B. Brandt (Moscow University) discovered, as a result of his studies of the magnetic susceptibility of bismuth at temperatures ranging from $o.o5^{o}$ to $o.1^{o}$ K, in fields of up to 13 ooo oersted (the author was the first to succeed in this undertaking at such temperatures), along with the usual oscillations, radio-frequency oscillations of the susceptibility, and came to a series of conclusions concerning the Fermi-surface, which is responsible for this appearance of a group of holes.

B.N. Aleksandrov, B.I. Verkin, and I.V. Svechkarev (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) studied the magnetic susceptibility of mono-crystal samples of indium, lead, and copper between room- and hydrogen temperature. They found that the anisotropy of the susceptibility changes strongly with the temperature. For example, the susceptibility of indium, lined up parallel to the major axis, grows by a factor of three if the temperature is lowered , while the direction perpendicular to the axis almost no changes exhibits. According to the authors these experiments prove the temperature variation of the susceptibility of the elements,

which show a large period de Haase - von Alfvén - effect, to be defined by unusually few groups of electrons.

B.I. Verkin and I.M. Dmitrïenko (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) measured the period of the susceptibility oscillations of mono-crystals of zinc as a function of pressures between o - 2ooo atms. To obtain the pressure data they utilized the critical temperature shift of a superconductive tin ring, which was placed inside a high-pressure vessel, and which surrounded the sample. The period of the oscillation turned out to be a rather complicated function of the pressure.

D. POLYMORPHISM, SEMICONDUCTORS AND OTHER PROBLEMS

I.A. Gindin, B.G. Lazarev, Ya.D. Starodubov and V.I. Khotkevich (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) presented a paper dealing with the future study of low temperature polymorphism. The number of metals with low temperature polymorphism has been somewhat extended: we have now in addition to tin, lithium, sodium, bismuth, mercury, and beryllium, also potassium and (with less certainty) zinc and magnesium. A survey of this list confirms the idea that this phenomenon is a characteristic of not-closely-packed metals. They obtained some data on the physical characteristics of the low temperature modification of bismuth, They also measured carefully the mechanical deformation curves at temperatures between $77^o - 99^o$ K, and defined the transition temperature more accurately (it is equal to $83^oK \pm 2^o$). The measurements of the electrical conductivity showed that the low temperature modification of bismuth possesses a higher conductivity, and that it changes (at about 7^o K) to its superconductive state.

B.G. Lazarev, E.E. Semenenko, and A.I. Sudovtsev (Physical-Technical Institute, Academy of Sciences, Ukranian

SSR) reported on the superconductivity of beryllium, and on its low temperature polymorphism. The research was conducted on thin films (thickness: 4oo - 15oo Å). The low temperature modification exists down to about 3o° K. First heating a sample to a higher temperature and then cooling it down to helium temperature, results in the superconductive transition (which is characteristic of the low temperature phase) not being complete any longer; by heating to 6o° K (this temperature is to a certain degree dependent on the exposure time) the low temperature modification disappears completely. They measured the resistance change curves, while the films were heated to room temperature; two levels were observed during this process: one near the actual low temperature modification and one after transition (about to 2oo° K). It is possible that the low temperature modification which can be observed in beryllium films, coincides with its low temperature modification due to the plastic deformation of the solid metal.

B.N. Samoilov, B.V. Sklyarevskii, and E.P. Stepanov (Atomic Energy Institute, Academy of Sciences, USSR) studied nuclear polarization of weakly magnetic elements, which were transformed into ferromagnetic materials, at super-low temperatures. The nuclear polarization parameters of In^{114}, Sb^{122}, and Au^{198}, diluted in iron at temperatures of several hundred degrees, are determined from the anisotropy of the γ-radiation of these nuclei ϵ. We can find the experimentally measured value $\sqrt{\epsilon}$, in accordance with existing ideas, from the effective internal magnetic field H at location points of the radioactive nuclei. An estimate of H showed that the internal field contributes, in this case, for indium, antimony, and gold more than 15o ooo, 34o ooo, and 1 2oo ooo oersted, respectively. The polarization level of the listed nuclei at the lower end of the achieved temperatures (3o - 5o%) was sufficient to conduct a

series of nuclear experiments. The technique applied in the nuclear polarization is apparently a common one.

A.V. Kogan reported that at the Leningrad Physical-Technical Institute analogous experiments were conducted with Sc^{56} and Co^{60} solutions in iron; they found values for the internal field, which were of about the same order of magnitude.

K.B. Vlasov (Institute of Physics of Metals, Academy of Sciences, USSR) studied theoretically the rotation of the polarization plane of elastic waves in metals, magnetically polarized by applying a magnetic field. The absorption of the supersonic frequencies in a magnetic field can formally be expressed through the dynamic tensor of the elasticity modulus, whose components are complex quantities and are functions of the magnetic field. New components of this tensor appear in the magnetic field, and new physical phenomena correspond to these components. In particular, there has to be a significant effect due to the rotation of the polarization plane of the cross-wise, elastic waves, which travel along the field; the rotation in a field of about 100 oersted has to be a few (maybe even tens of degrees) degrees for 1 cm of sound path.

The experiment conducted by N.I. Krivko, A.I. Gubanov, and N.M. Reinov (Leningrad Physical-Technical Institute, Academy of Sciences, USSR) aroused great interest. The authors studied the dynamic resonance of Cu_2O crystals at liquid helium temperature. They conducted their measurements on 3 x 3 x 1 mm slabs, which were positioned in the loop (antinode?) of the electric field inside a wave guide; the wave length was about 3 cm. The absorption spectra they found confirm the existence of polarons (polyaronii) in copper oxide. The efforts made it possible to estimate the effective mass of a polaron: it is about 6 - 7 times the mass of an electron.

Five papers on semiconductors were discussed during the

general session (all, except for one, were written at the Institute for Semiconductors, Academy of Sciences, USSR). The first three reports - S.S. Shalita and I.N. Timchenko; I.V. Mochan and T.V. Smirnovoi; Yu. N. Obraztsova - dealt with studies of entrainment characteristics of current carriers in semiconductors, which move during the heat propagation process of the phonons (this phenomenon was predicted and was calculated for metals by L.E. Gurevich). The first lecture reported on the thermo-electromotive force (termo - e.d.s. = termo-elektrodvizhyushchaya sila ?) of tellurium at temperatures between 2^{o} - $3oo^{o}$ K. The thermo -emf shows at low temperatures (less than $5o^{o}$ K) a sharp increase, which soon starts to drop as the temperature decreases further (less than 8^{o} K). The change in the thermo - emf with temperature conforms satisfactorly with the results, which were deduced from the theory of interaction between a non-equilibrium phonon distribution and the current carriers in a non-uniformly heated semiconductor. The second report dealt with the influence entrainment has on the thermo-magnetic effect in p - germanium. The temperature dependence of the parallel and the normal effects were investigated. The relaxation times, as functions of the temperature, characterizing the interaction of "holes" and electrons with parallel long-wave phonons, turned out to conform. Yu.N. Obraztsova's report submitted a theory on the influence of the entrainment of the current carriers through phonons on the thermo-magnetic effects in semiconductors. The theoretical curves are close to the experimental results of I.V. Mochan and T.V. Smirnovoi.

G.E. Pikus' and G.L. Bir's theoretical paper dealt with the influence of mechanical deformation on the characteristics of semiconductors with complicated internal structures. The low temperature electrical characteristics of semiconductors must change sharply (change in effective carrier mass, emergence of

anisotropy, etc.) as their energy spectrum degenerates during the deformation, which causes the change in the symmetry of the crystal. This phenomenon can be expected in cubic crystals at temperatures of about o.1° K, and at relative deformations of the order of $1o^{-4}$.

I.M. Lifshits and M.I. Kaganov (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) conducted a theoretical study of the electron resonance in semiconductors in crossed electric and magnetic fields. As we know, a free electron drifts in crossed fields in a direction normal to both fields, and simultaneously oscillates with a Larmor frequency $\omega = \frac{e}{m}\frac{H}{c}$. The frequency of the oscillations of a solid conductor is determined from the dispersion law. Experimentally this may appear in the dependence of the dynamic frequency on the current passing through the sample. The frequency change of the resonance is $\frac{\Delta\omega}{\omega} \sim \frac{c}{v}\ \frac{E}{H}$ (for small electric fields). This effect must be small in metals, as the E is small for a given current. A quadratic dispersion law usually applies to semiconductors. However, it appears that this effect has to be observed in germanium and silicon with "holes", where the dispersion law deviates from the quadratic form; in this case, apparently we may expect an effect of about 3o%, with an electric field of about 4o - 5o $\frac{\text{webers}}{\text{cm}}$. In metals we will most probably observe this effect in bismuth.

Reports by the representatives of the symposia, taking place during the days of the meeting, were given to the general session on the final day. These reports were given by I.M. Lifshits, M.P. Malkov, S.S. Shal't, and A.N. Orlov. They were brief summaries of papers discussed at the symposia. One of the papers, a paper by I.M. Lifshits on kinetics of the process of establishing an order, produced a lively discussion among the participants of the conference. The problem is the following:

A system is transferred by means of hardening into temperature regions below the phase transition point (the "ordered" region), and the process of establishing order is studied as a function of time. The simplest cases of the system, characterized by two states: "+" and "-" (for example, "up" or "down" ion spin), were analyzed completely. The entire space is divided, during the process of establishing order, into alternating domains of "+" and "-". The process advances in the direction of decreasing the surfaces of the "spider-web" boundaries, so that the domain will increase gradually. The disadvantage of the boundary surfaces with respect to the entropy plays the most important role. The mean size of the domains $\bar{R}$ grows with time t according to $\bar{R} \approx \sqrt{(a^2/\tau)\cdot t}$ (where a - parameter of the lattice, τ - characteristic time), until the domains become the same order of size as a crystallite; after that the domains "eat" each other. The characteristic time τ it takes to establish an order in a solid solution is apparently of the order of fractions of a second up to minutes; it seems to be, for the case of an antiferromagnetic transfer, of the order of 10^{-8} sec. This study is of great interest in low temperature Physics, where we often deal with phase transfer of the second kind.

The following reports were also given at the symposia. I.A. Kvasnikov and V.V. Tolmachev (Mathematical Institute, Academy of Sciences, USSR) studied a few possibilities of applying methods of the superconductivity theory to problems of the basic state of antiferromagnetic materials, and attempted to estimate the energy of this particular state. The Polish scientist Z. Golyasevich (Joint Institute of Nuclear Research) analyzed the interaction system of fermions (fermionii) (superconductor), and showed that in the excitation spectrum of such a system there may exist a branch, corresponding to a pairing of particles with equal spin (something of the order of spin waves).

L.P. Pitaevskii, E.M. Lifshits, and I.E. Dzyaloshinskii (Institute for Problems in Physics) analyzed the characteristics of a helium II film. They showed that an additional term enters the thermodynamic potential of the film, which is a function of the thickness of the film, d, and obeys the function A/d^3; the constant A can be expressed through the characteristics of the film and its backing. Yu. G. Mamaladze and S.G. Matinyan (Tiblisi University) conducted a theoretical study of the influence rotation has on the oscillatory damping coefficient of a disc in helium II, and explained some of the peculiarities of this phenomenon, which were observed experimentally. B.N. Esel'son (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) told about the use of carbon absorption pumps to obtain low temperatures (temperatures of the order of 0.8° K can easily be attained). N.B. Brandt (Moscow University) reported on simple spring scales with a sensitivity of 0.05 mg, and on a method of obtaining high pressures (up to 10 000 - 20 000 atms) at low temperatures. A.G. Zel'dovich (Joint Institute of Nuclear Research) reported on the development and the starting up of anionization chamber, based on liquid hydrogen, with a volume of 50 l, and which operates in a magnetic field of 14 000 oersted, also on the production of hydrogen with 80% para-hydrogen (the evaporation rate of such converted hydrogen is, compared to normal hydrogen, when stored, drastically reduced), and finally also on a method developed at their institute, permitting gases in liquifiers to be cleaned of oils. I.D. Kurova (Moscow University) reported on studies of characteristics of extremely pure germanium at temperatures of 300°-2.5° K. E.I. Zavaritskaya reported on research done jointly with B.M. Wool (Vul) on the temperature function of the (p-n)-transfer in germanium, over a wide temperature range. I.A. Gandin (Physical-Technical Institute, Academy of Sciences, Ukranian SSR) studied

the influence of the preliminary plastic deformation of technical iron on its mechanical characteristics at low temperatures, in particular, the influence on its elastic limit. N.M. Reinov and A.P. Smirnov (Leningrad Physical-Technical Institute, Academy of Sciences, USSR) found the elastic limits of monocrystals of tin and indium at temperatures of about o.1° K. They utilized the superconductivity of these metals to obtain the data.

P.L. Kapitsa summarized, in the closing words of the conference, the results of the meeting.

The VII All - Union meeting on low temperature Physics is scheduled to take place in Kharkov during June or July 196o.

R. Chentsov

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